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ANALYSIS OF MEDIAN LIGHTING

State of the Art

Final Report

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16. Abstract

Highway lighting is provided to facilitate a safe movement of vehicular traffic during the nighttime. Highway median lighting is popular due to its economic and service advantages. Economic advantage results from reducing the number of supports, and service advantage is a product of better visibility along the median and inside higher speed lanes.

The purpose of this study was to study all the pertinent aspects of median lighting. More specifically, to conduct a literature review, study policies and procedures in different states, and recommend future research if needed.

A survey questionnaire, designed to review different procedures pertaining to median lighting, was mailed to eighty-six members of the AASHTO Traffic Committee.

The study concluded that more research effort is needed in the area of public safety associated with lighting routine maintenance. A work plan was developed which identified the proposed study objectives and the corresponding tasks needed to conduct this research.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

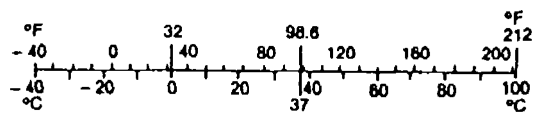
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

Table of Contents

INTRODUCTION

The principal purpose of roadway lighting is to maintain quick, accurate and comfortable visibility at night. These qualities of vision combine to safeguard, facilitate and encourage vehicular and pedestrian traffic during night [1].

Over the years, the basic motivation of people desiring artificial lighting at night has remained unchanged. The visual information needs of the modern driver are catered to by fixed roadway lighting which manifest themselves as reduced accident costs, reduced damage to roadway structures and increased business in downtown areas [5].

In the past, when the road geometrics did not include medians (among other design elements), the only pattern of lighting configuration used to be side-mounted i.e. on the sides of the travelled way (either staggered or opposite). However, nowadays median-mounted lighting configuration is employed whenever applicable. The choice of the type of lighting configuration is dependent upon many factors which include the type of roadway facility, the ambient land use, the illumination demand, the road geometrics and the lighting hardware. The current guidelines and practices of fixed roadway lighting are stipulated in the American National Standard Practices for Roadway Lighting by the

Illuminating Engineering Society [8] and in the AASHTO's guide for roadway lighting [3].

The last few decades have seen great developments in the areas of lighting hardware (such as light sources, lighting poles or standards, mounting heights, etc.), land use surrounding the roadway facility and traffic volumes. Literature is replete with the above-mentioned improvements and their impacts on the roadway lighting system. The lighting configuration has been improved considerably and more efficient, safe and comfortable lighting is in use. Many of these literature sources discuss one or more aspects of median lighting but none of them address the subject exhaustively.

This report attempts to study all the pertinent aspects of median lighting such as illumination demand, roadway and area classifications, and design of lighting system (configuration, hardware and spacing). It comprises of background information, a literature review, a study of the policies and procedures regarding median lighting in different states, a summary of the findings and recommended future research, if needed.

RESEARCH OBJECTIVES

The objective of this research is to prepare a state-of-the-art report and develop a research work plan for any recommended research.

The following tasks were performed :-

i) Review of all available literature related to this subject.

ii) Investigate the experience of using the median roadway lighting in Arizona as well as other states.

iii) Investigate the policies and procedures used by various traffic engineering agencies.

iv) Provide a recommendation for future research which would lead to development of a uniform policy or guidelines in use of median roadway lighting.

v) Develop a detailed work plan for any recommended research and establish the anticipated project duration and estimated budget.

vi) Prepare a state-of-the-art report summarizing the findings of this study.

BACKGROUND INFORMATION

The design of roadway lighting includes many other aspects besides the configuration selection. But before venturing into the area of roadway lighting system design it is advisable to familiarize oneself with the terminologies and definitions commonly used in this field.

Some of the important definitions (alphabetically listed) are as follows [1] :-

(i) Ballast :- a device used with an electric-discharge lamp to obtain the necessary circuit conditions (voltage, current and wave-form) for starting and operating.

(ii) Candela, cd :- (formerly candle) the unit of luminous intensity. One candela is defined as the luminous intensity of 1/600,000 square meter of projected area of a black body radiator operating at the temperature of solidification of platinum under a pressure of 101,325 newtons per square meter.

(iii) Footcandle, fc :- the unit of illumination when the foot is taken as the unit of length.

(iv) Footlambert, fL :- a unit of luminance (photometric brightness) equal to 1/pi(3.1412) candela per square foot.

(v) Incandescent filament lamp :- a lamp in which light is produced by a filament heated to incandescence by an electric current.

(vi) Lambert, L :- a unit of luminance equal to 1/pi(3.1412) candela per square centimeter.

(vii) Lamp post :- a standard support provided with the necessary internal attachments for wiring and the external attachments for the bracket and luminaire. Also, light pole and lighting standard.

(viii) Lumen, lm :- the unit of luminous flux. It is equal to the flux through a unit solid angle (steradian), from a uniform point source of one candela.

(ix) Luminaire :- a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

(x) Lux, lx :- the International System (SI) unit of illumination. It is the illumination on a surface one square meter in area on which there is a uniformly distributed flux of one lumen.

(xi) Mercury lamp :- an electric discharge lamp in which the major portion of the radiation is produced by the excitation of mercury atoms.

(xii) Metal Halide lamp :- a discharge lamp in which the light is produced by the radiation from a mixture of a metallic vapour and the products of the dissociation of halides.

(xiii) Mounting height :- the vertical distance between the roadway surface and the center of the apparent light source of the luminaire.

(xiv) Spacing :- for roadway lighting, the distance between successive lighting units, measured along the centerline of the street.

There are two methods of discernment of an object during nighttime : discernment by silhouette and discernment by surface detail. Discernment by silhouette occurs when the general luminance level of all or a substantial part of the object is lower or higher than the luminance of its background. Discernment by surface detail takes place when an object is seen by the virtue of variations in brightness or colour over its own surface, without regard to its contrast with its background [2]. Both of them are enhanced by better roadway lighting.

The minimum amount of illumination required has been found to depend upon the type of roadway facility and ambient land use [1]. The roadway and walkway classifications (groupings of roadway types) are listed below followed by area classifications (type of surrounding land use) [1,8].

<u>Roadway and Walkway Classifications</u> :-

(i) <u>Major</u> :- The part of the roadway system that serves as the principal network for through traffic flow connecting areas of principal traffic generation and contact points of major rural highways entering the city.

(ii) <u>Collector</u> :- The distributor and collector roadways serve traffic between major and local roadways.

(iii) <u>Local</u> :- Roadways used primarily for direct access to residential, commercial, industrial or other abutting property.

(iv) <u>Expressway</u> :- A divided major arterial highway for through traffic with full or partial control of access and generally with interchanges at major crossroads.

(v) <u>Freeway</u> :- A divided major highway with full control of access and with no crossings at grade.

(vi) <u>Alley</u> :- A narrow public way within a block, generally used for vehicular access to the rear of abutting properties.

(vii) <u>Sidewalks</u> :- Paved or otherwise improved areas for pedestrian use, located within public street rights-of-way which also contain roadways for vehicular traffic.

(viii) <u>Pedestrian Ways</u> :- Public sidewalks for pedestrian traffic generally not within rights-of-way for vehicular traffic roadways (includes skywalks, subwalks and walkways giving access to park or block interiors and crossings near centers of long blocks).

Area Classifications :-

(i) Commercial :- This definition applies to densely developed business areas outside of, as well as those that are within, the central part of a municipality (includes downtowns and large shopping malls).

(ii) Intermediate :- This definition applies to densely developed apartment areas, hospitals, public libraries and neighbourhood recreational centers. These are areas outside downtowns but within the zone of influence of a business or industrial development.

(iii) Residential :- This definition applies to a mixture of residential and commercial establishments with low volumes of pedestrian and vehicular traffic and low parking demand (includes areas with single family homes, townhouses, small apartments, regional parks, cemeteries and vacant lands).

LITERATURE REVIEW

The design of any roadway lighting system starts off with the assessment of the lighting needs (i.e. judging the necessity of roadway lighting and determining the required amount of illumination). After this step, the lighting equipment is selected to satisfy the illumination demand. Next, the lighting configuration is chosen. This is followed by analysis of the selected equipment (i.e. selection of light source, luminaire type, mounting height, luminaire spacing and location). The next step is to design the hardware (i.e. selection of pole foundations and mounting hardware, method of supply of electrical energy etc.). The lighting systems operation and maintenance is the subsequent area of consideration. Last but not least, the economics of the lighting system is analyzed.

The above is the general procedure of overall design of a lighting system [2]. The individual steps mentioned above have been reviewed in more detail in the following paragraphs with stress on median lighting.

4.1 Assessment of lighting needs :- One school of thought believes that all roadways should be well illuminated with fixed light sources while the other believes that the vehicle lighting is more than necessary for all roadways [2]. The actual lighting need is somewhere in between these two.

The Joint Task Force for Highway Lighting of the AASHTO Operating Subcommittees on Design and Traffic Engineering [3] has developed warrants (factual evidences justifying or standing as assurances that there is substantial reason for undertaking a proposed project) which stipulate conditions that must be satisfied to provide lighting. But the satisfying of these warrants does not obligate the highway agency to provide lighting. These warrants may be modified for local conditions (such as frequent occurrences of fog, ice or snow) or one or more of these warrants may be utilized for justifying the installation of fixed roadway lighting.

The Roadway Lighting Handbook [2] suggests that these warrants should be based upon conditions relating to the need for roadway lighting and the benefits therefrom (i.e. on factors like traffic volume, speed, road use during the night, night accident rate, road geometrics and general night visibility). Justification for lighting should also be based upon the economic returns of lighting as compared to the costs of not lighting; economic returns for lighting being measured in terms of reductions in personal injuries, fatalities, property damage and other societal costs. More effective usage of the road and the possible increase in its capacity should also be considered.

Walton and Messer [4] have developed a warranting scheme for roadway lighting based upon whether efficient and effective vehicle control can be achieved. Driver visual work is used as the measure of effectiveness for visual control. Driver work load or information demand is expressed in driver task levels identified as positional, situational and navigational as described below :-

i) The positional level must always be satisfied before other levels can be attended to. It consists primarily of routine speed and lane position control.

ii) The situational level comes next but before navigational level. It consists of change in speed, direction of travel, or position on the roadway because of a change in the geometrics or in the operational or environmental situation.

iii) The navigational level is performed only if levels 1 & 2 are satisfied. It consists of selecting and following a route from origin to destination.

Information demand is defined to be the time, in seconds, required to fulfill a sequence of positional, situational, navigational and redundant positional information searches. Information supply is defined as the time, in seconds, representing the visibility distance ahead for a given operating speed. When information demand exceeds information supply without roadway lighting, then roadway lighting is assumed to be warranted. The authors have supplied formulae and computations for information demand, information supply, warranting conditions etc.

AASHTO warrants are developed for five principal areas of roadway lighting viz. freeways, interchanges, tunnels and underpasses, roadway safety rest areas and roadway sign lighting. References 3 & 5 are excellent sources for details on these topics.

As far as the levels of illumination are concerned, the Illuminating Engineering Society has recommended (in the American National Standard Practice for Roadway Lighting) [8] minimum illumination levels for different roadway and area classifications. They are presented in Table 1. These values are only but suggested ones and should be modified according to the local prevalent environmental conditions on the roadway in question.

The uniformity of light distribution has proven to be at least equally as valuable as the illumination level in providing a satisfactory nighttime driving environment [5]. The National Standard Practice recommends an average to minimum ratio of 3:1 while AASHTO specifies 3:1 to 4:1 as shown in Table 2. The uniformity of illumination helps the driver to clearly and accurately visualize all the objects on and near the roadway.

The high mounting heights (40-60 ft.) have been recognized by the Standard Practice [8] and AASHTO guide [3]

Table 1

RECOMMENDATIONS FOR ROADWAY AVERAGE MAINTAINED HORIZONTAL ILLUMINATION

Vehicular Roadway Classification	Commercial Footcandle	Commercial Lux	Urban Intermediate Footcandle	Urban Intermediate Lux	Residential Footcandle	Residential Lux
Freeway*	0.6	6	0.6	6	0.6	6
Expressway*	1.4	15	1.2	13	1.0	11
Major	2.0	22	1.4	15	1.0	11
Collector	1.2	13	0.9	10	0.6	6
Local	0.9	10	0.6	6	0.4	4
Alleys	0.6	6	0.4	4	0.4	4

NOTE: The recommended illumination values shown are meaningful only when designed in conjunction with other elements. The most critical element as described in this practice are as follows:

(a) Illumination depreciation
(b) Quality
(c) Uniformity
(d) Luminaire mounting heights
(e) Spacing
(f) Transverse location of luminaires
(g) Luminaire selection
(h) Traffic conflict areas
(i) Border areas
(j) Transition lighting
(k) Alleys
(l) Roadway lighting layouts

*Both mainline and ramps

Source : Roadway Lighting Handbook (Reference 2)

Table 2

RECOMMENDED AVERAGE-TO-MINIMUM UNIFORMITY RATIOS		
	Recommended Ratios	
For Roadways in	IES/ANSI (2)	FHWA/AASHTO (3)
Commercial Areas	3:1	4:1
Intermediate Areas	3:1	4:1
Residential Areas	6:1	6:1

Source : Roadway Lighting Handbook (Reference 2)

as a means of glare reduction. They have been possible with the advent of larger and more efficient light sources. It has other advantages , such as fewer poles, possible lower over-all system costs, increased safety and increased comfort through improved uniformity.

4.2 Selection of lighting equipment :- This step is important to ensure that the lighting system serves its intended purpose efficiently and economically. The lighting equipment includes lamps, luminaires and structural supports.

There are two general types of light sources - filament lamps and arc-discharge lamps [1]. Filament lamps include incandescent, tungsten-halogen and photo-lamps. The arc-discharge lamps include fluorescent, high intensity discharge (H.I.D.), Xenon, Carbon-arc and other flame arc lamps.

In the past, only one type of lamps were in use i.e. incandescent lamps. But recently a gradual change to discharge type lamps has taken place. The trend of using these (more efficient) H.I.D. light sources is on the rise because of the ever-increasing power costs and the concern to preserve our energy resources. Table 3 provides a tabular listing of typical area and roadway lighting lamp characteristics.

Table 3

TYPICAL AREA AND ROADWAY LIGHTING LAMP CHARACTERISTICS

	Lumens Per Watt								Cost	
	(Includ. Ballast Losses (2.)	Lamp Only	Lumens	Wattage Range	Rated Ave. Life (hrs.) (3.)	% Maint. Output at end of life	Color Rendition	Optical Control	Initial (Lamp)	Operational (Power)
Incandescent(5)	N/A	11-18	655-15300	58-860	1500-12000	82-86	Exc.	Excellent	Low	High
Tungsten-Halogen	N/A	20-22	6000-33000	300-1500	2000	93	Exc.	Exc. Vertical Poor Horiz.	Moder.	High
Fluorescent	58-69	70-73	4200-15500	60-212	10000-12000	68	Good	Poor	Moder.	Moder.
Mercury-Clear	37-54	44-58	7700-57500	175-1000	24000+	62-82	Fair	Good	Moder.	Moder.
Mercury-W/Phosp.	41-59	49-63	8500-63000	175-1000	24000+	50-73	Good	Fair	Moder.	Moder.
Metal Halide	65-110	80-125	14000-125000	175-1500	7500-15000 20000	58-74	Good	Good	High	Low
High Pressure Sodium	60-130	83-140	5800-110000	70-1000	20000-24000	73	Fair	Good	High	Low
Low Pressure Sodium	78-150	131-183	4650-33000	35-180	18000	100(4.)	Poor	Poor	High	Low

NOTES:

1. All figures show operating ranges typical for lamp sizes normally used in area and roadway applications.
2. Ranges shown cover low wattage lamps with regulated type ballasts (worst condition) through high wattage lamps with reactor type ballasts (best condition).
3. Rated average life is based on survival of at least 50% of a large group of lamps operated under specified test conditions at 10 or more burning hours per start.
4. Low pressure sodium lamps maintain initial lumen rating throughout life, but lamp wattage increases. Considering this change in wattage, the luminous efficacy of these lamps (including ballast losses) at 18000 hours is 67-117 lumens per watt.
5. Larger sized incandescent lamps (up to 2000 watts) for floodlighting applications are available. Depending on operating conditions, the luminious efficacy and life change considerably for these lamps from the typical values shown. Lamp schedules should be consulted for details.

Source : Roadway Lighting Handbook (Reference 2)

A luminaire is defined as a complete lighting unit consisting of a lamp (or lamps) together with the parts designed to distribute the light, to position and protect the lamp(s) and connect the lamp(s) to the power supply [1]. It is comprised of a group of components (together called the optical system, the electrical system and the mechanical system) clubbed together in terms of their functions.

The optical system includes the light source and the reflector & the refractor (to direct the light). The electrical system includes the lamp sockets, the ballast, a terminal block (the point where connections to supply lines are made), a fuse (to protect the supply side of an installation), lightning arresters (to protect ballasts and lamps from damaging voltage surges), a photoelectric control (to turn the lighting equipment on and off automatically at dusk and dawn) and internal wiring (to connect various electrical components). The mechanical system serves to package all of the optical and electrical system in an orderly way for proper positioning and protection of the lamp, ease of luminaire operation and maintenance, minimal weight and windloading and a pleasing daytime appearance.

A number of different types and qualities of above-mentioned equipment are available today, each to serve a specific problem of lighting. References number 1, 2 and 8 provide considerable detail in this area.

The subject of design of lighting system utilizing pavement luminance has been addressed at great lengths in the addendum to the Roadway Lighting Handbook [6].

The lighting standards or light poles can be of various types viz. steel (galvanized, painted, or weathering steel), aluminum, stainless steel, wood and concrete. Also, There are several bases available to support the light poles. The selection of a particular type of base depends on the method of construction, type of pole, funds available, agency policy and safety. However, safety is the most important consideration [2]. The poles used for median lighting are invariably with breakaway bases or mounted over concrete median barriers. As per the recommendations of state and national agencies, the median lighting pole is one of the types of lighting supports that are exposed to traffic. The use of median lighting does increase the hazards due to increased number of roadside structures close to the travelled roadway.

The acceptability of breakaway devices for use depends upon the dynamic performance of the breakaway supports under automobile impact is the basic measure of satisfactory breakaway characteristics. Satisfactory dynamic performance is indicated when the maximum change in momentum for a standard 2250 pound (1020 kg) vehicle, or its equivalent, striking a breakaway support at speeds of 20 to 60 mph (32km/h to 96 km/h) does not exceed 1100 pound-seconds (4893

N-sec) but desirably does not exceed 750 pound-seconds (3336 N-sec). There are numerous types of luminaire supports and bases currently in service. Each of them are for use at specific conditions [2].

<u>4.3 Selecting the lighting system configuration</u> :- The right selection of lighting system configuration is important in utilizing the already chosen equipment to best satisfy the demands. There are two most common lighting systems in use today viz. side-mounted system and median-mounted system (fig. 1). In this report we will discuss the median-mounted system of lighting configuration. The side-mounted system has been in use since a long time and used to be the only configuration due to the absence of medians. In the recent years the median-mounted system has become very popular.

One of the most important features of this system is economy [2]. As compared to the side-mounted system, the number of supports required is reduced by one half. Also, due to only one row of supports, there is need of only one row of electrical conductors. Savings in material and construction costs are substantial. In addition to the economic advantage of median lighting, there is a service advantage - median lighting provides better visibility. The illumination level dissipates slowly across the traffic lanes and out into the areas adjacent to the roadway. The highest level of illumination is along the median and inside higher speed lanes. The horizontal light component is

TYPICAL MOUNTING CONFIGURATIONS
(LUMINANCE PATTERNS REPEAT AT SPACING BOUNDARIES INDICATED)

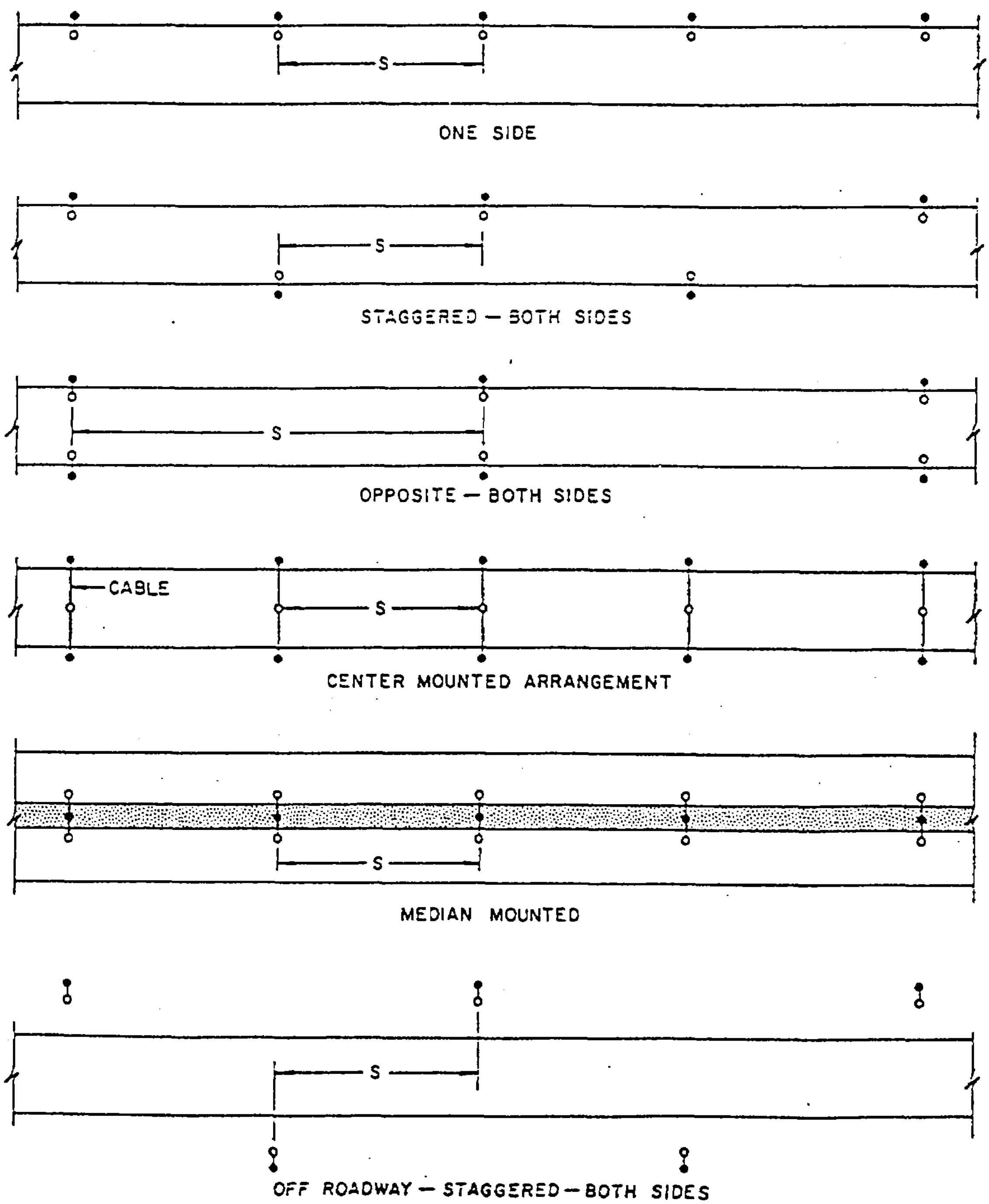


Figure 1

Source : Addendum to Roadway Lighting Handbook (Reference 6) proportionately high in the border areas and aids the driver's visibility. On the other hand, in side-mounted system the illumination system is highest along the edge of the roadway, between the driver and the peripheral area. This creates a brightness curtain that reduces the visibility of the driver beyond the edge of the roadway. The illumination effects of the two systems are shown in the diagrams here (fig. 2) [2].

Due to the economic and service factors discussed above median lighting should be the first consideration in lighting the main lanes of freeways and expressways. However, there are several cases where median lighting may not be the most applicable [2]. Some of them are :-

i) Freeways and expressways where the median is to be used for transit vehicles.

ii) Freeways and expressways where there is no median barrier and the relative hazard of fixed-object collisions would be increased.

iii) Freeways and expressways on separate alignment or where the median is too wide for both directional roadways to be lighted from one mast.

iv) Freeways and expressways in urban areas where the facility is depressed.

It has been established by experience, that breakaway bases should be used on the intermediate to high speed traffic facilities such as freeways and expressways when

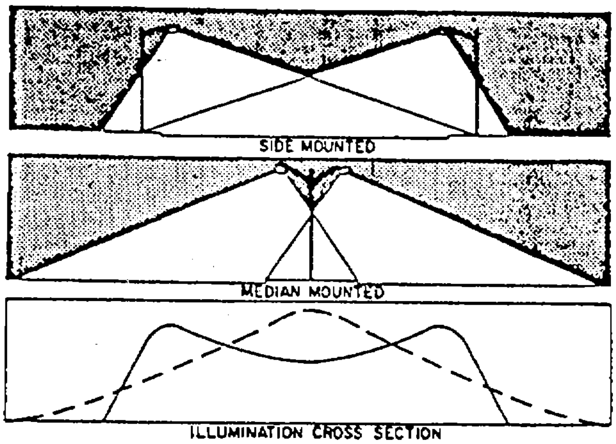


Figure 2 Comparative distribution of illumination for median vs. side-mounted systems.

Source : Roadway Lighting Handbook (Reference 2)

median-mounted lighting is used without a median barrier. When luminaire supports are integrated with a median barrier, breakaway bases may or maynot be applicable depending upon the type and characteristics of the median barrier. There are three basic types of median barriers available viz. flexible, semi-rigid and rigid depending upon the amount of deflection allowed during impact [2].

On the arterial with a distinct median, the most accepted and practiced form of lighting system is median-mounted. Although there should be very few intersections for the median type of lighting to be applicable, designers have simply located the luminaire supports on the median nose adjacent to auxiliary turning lanes with very little lateral clearance. Placement of luminaire supports in the medians on the arterial definitely increases the exposure to fixed object hazards in the sense that vehicles going out of control can impact the luminaire supports located in the median. But the same kind of impact can result from vehicles going out of control to the right and striking luminaire supports located in side-mounted configuration. The only difference in these two cases is the trajectory of the support after the collision i.e. the light pole can be driven into the opposing lanes of traffic after breaking loose, in the median-mounted system. However, this configuration of highway lighting is used very frequently (when applicable).

4.4 Analysis of the selected equipment :- The overall objective criterion of lighting should be to achieve good visibility through effective utilization while minimizing energy consumption to provide that illumination. The first objective is to make sure that the light sources used are of adequate efficiency. A second means of conserving energy would be to use minimum illumination needed and not to overlight. A third criterion would be to see that lighting is done only where needed (i.e. to check the conditions stipulated by the lighting warrants).

To check the quantity and quality of illumination one should refer the standard practices and guidelines mentioned earlier and to see that the uniformity ratios are within the tolerance levels (Table 2). There are computational formulae available which can be used to calculate the luminaire lateral location and spacing once the light source size and mounting heights are selected [2].

4.5 Design of lighting hardware :- This subsection deals with the method by which the electrical energy is supplied to the individual luminaires and selection of pole foundations and mounting hardware which will support the luminaire and pole under anticipated loading conditions.

The electrical distribution system encompasses basically the switching on and off of the luminaires and distributing electrical energy to the luminaires. Various types of circuits are required and are designed for various group sizes and types of luminaires. The luminaire support hardware comprises of mast arm, the pole, the foundation and a transformer base. Each of them are designed to support its own weight and the weight of the luminaire under different loading conditions. These topics are discussed in detail in the Roadway Lighting Handbook [2].

<u>4.6 Lighting system operation and maintenance</u> :- The continued effectiveness of a lighting system is as much a result of good operation and maintenance procedures as it is of good design in its initial development. To ensure this, routine and emergency maintenance are required. In fact, careful routine maintenance can reduce the probability of emergency maintenance. In short, the agency which is responsible for the operation of a lighting system should provide for the power to be supplied to the system, monitor the system and maintain the system.

<u>4.7 Analysis of the economics of the lighting system</u> :- All proposals for highway improvements have to be economically analyzed to check if the public is getting the best possible return for their investment.

There are many instances where delineation and or pavement markers more than satisfy the nighttime visibility requirements as compared to fixed roadway lighting. Cost-effectiveness analysis can be used to choose preferred lighting designs for different situations in which lighting is warranted. Summarizing the effectiveness and cost for each feasible lighting design, one should choose, using judgment, the best design. The best design, together with its effectiveness and cost, is the design selection for priority competition with other improvements.

The median lighting is a cost effective lighting system configuration as compared to other configurations in the situations (when applicable).

ARIZONA'S EXPERIENCE WITH MEDIAN LIGHTING

The concept of median lighting configuration is not new for Arizona. The following are some of the locations (in Arizona) where median lighting has been in use :-

i) At Tucson, on I-10 and interchange with I-19. They were installed in 1981. The poles are installed in the New Jersey barriers and the mounting height is 50 feet.

ii) On I-10 (till 40th street) in Phoenix. The lamps are of 400 watts power and three in number per pole. The mounting height is 70 feet and the luminaire spacing is 100 feet.

iii) At the 4th Avenue and 16th Street with I-8 in Tucson. The poles are not installed on New Jersey barriers.

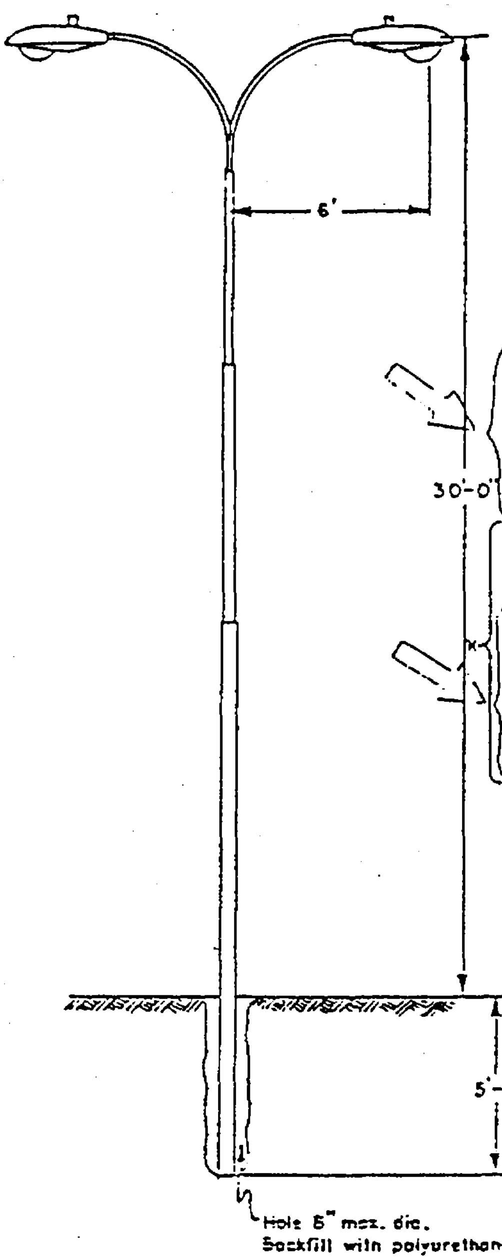
iv) On highway 89 and Glen Street in Tucson. The median is raised 10 inches and is 10-12 feet wide.

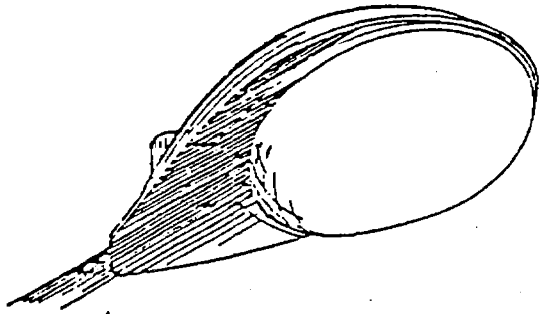
v) At Hohokam and University Drive in Phoenix

The city of Phoenix utilizes 250 watt lamps (30,000 lumens approx.) at a spacing of 200 feet and mounting heights of 50 feet (median-mounted and side-mounted) for collector and main streets. For the local and residential streets, the lamp power is 100 watts at a spacing of 450 feet but almost all of the times they are in side-mounted configuration. Most of the recently installed and future lighting fixtures have and will be having cobra-head cutoff lamps so that the light beams do not go upwards (i.e. cut down light pollution). The bases of all the light poles are breakaway type. None of them are machined or set in concrete. The lower ends of these poles are buried in the ground below the median, as shown in figure 3.

There are standard drawings of the specifications of various types of lighting poles, mast arms, bases etc. Some sample drawings are included in figures 4, 5 & 6. The general guidelines for installation of roadway lighting systems are laid down by the Arizona Department of Transportation in their publication Traffic Engineering - Policies, Guides and Procedures [7].

The experience of Arizona with the installation of median lighting has been a safe one. A study of accidents occurring in the last five years (1984 onwards) involving vehicles and light poles (obtained from the Motor Vehicle Division of the Arizona Department of Transportation) show no case of median lighting involvement. This suggests that installation of median lighting poles has not been a cause of increased hazard on the road. In fact, they have enhanced the roadway illumination and resulted in savings for the state and local agencies. As mentioned earlier also, median lighting involves laying of only one conduit along the road (approximate expense is $ 4 per foot). It has been felt by the local agencies that the maintenance of this system is





CODE NO.	UNIT DESCRIPTION
L31212T #	31' STEEL POLE, W/2 21,000 LUMEN, MV, 2-WAY
L3121DT	31' STEEL POLE, W/2 21,000 LUMEN, MV, D-D
LHC3116T #	31' STEEL POLE, 16,000 LUMEN, HPS
LHC3116DT	31' STEEL POLE, 16,000 LUMEN, HPS
LH©3130T #	31' STEEL POLE, W/2 30,000 LUMEN, HPS, 2-WAY
LH©3130DT	31' STEEL POLE, W/2 30,000 LUMEN, HPS, D-D
UL31212T #	31' STEEL POLE, W/2 21,000 LUMEN, MV, 2-WAY
UL3121DT	31' STEEL POLE, W/2 21,000 LUMEN, MV, D-D
ULHC3116T #	31' STEEL POLE, 16,000 LUMEN, HPS
ULHC3116DT	31' STEEL POLE, 16,000 LUMEN, HPS
ULH©3130T #	31' STEEL POLE, W/2 30,000 LUMEN, HPS, 2-WAY
ULH©3130DT	31' STEEL POLE, W/2 30,000 LUMEN, HPS, D-D

* SERVED UNDERGROUND

\# ADD 'P' TO COMPATIBLE UNIT CODE NUMBER WHEN THIS INSTALLATION IS TO BE USED FOR PRIVATE STREET LIGHTING.

© ADD 'C' TO COMPATIBLE UNIT CODE NUMBER TO OBTAIN CUTOFF TYPE FIXTURE.

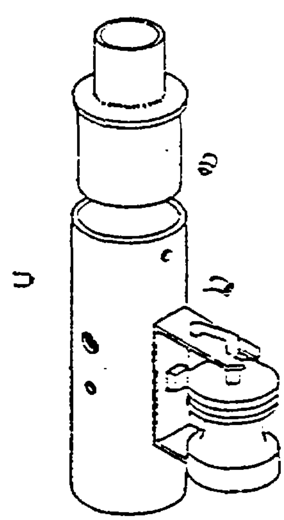


Figure 3

Source : City of Phoenix

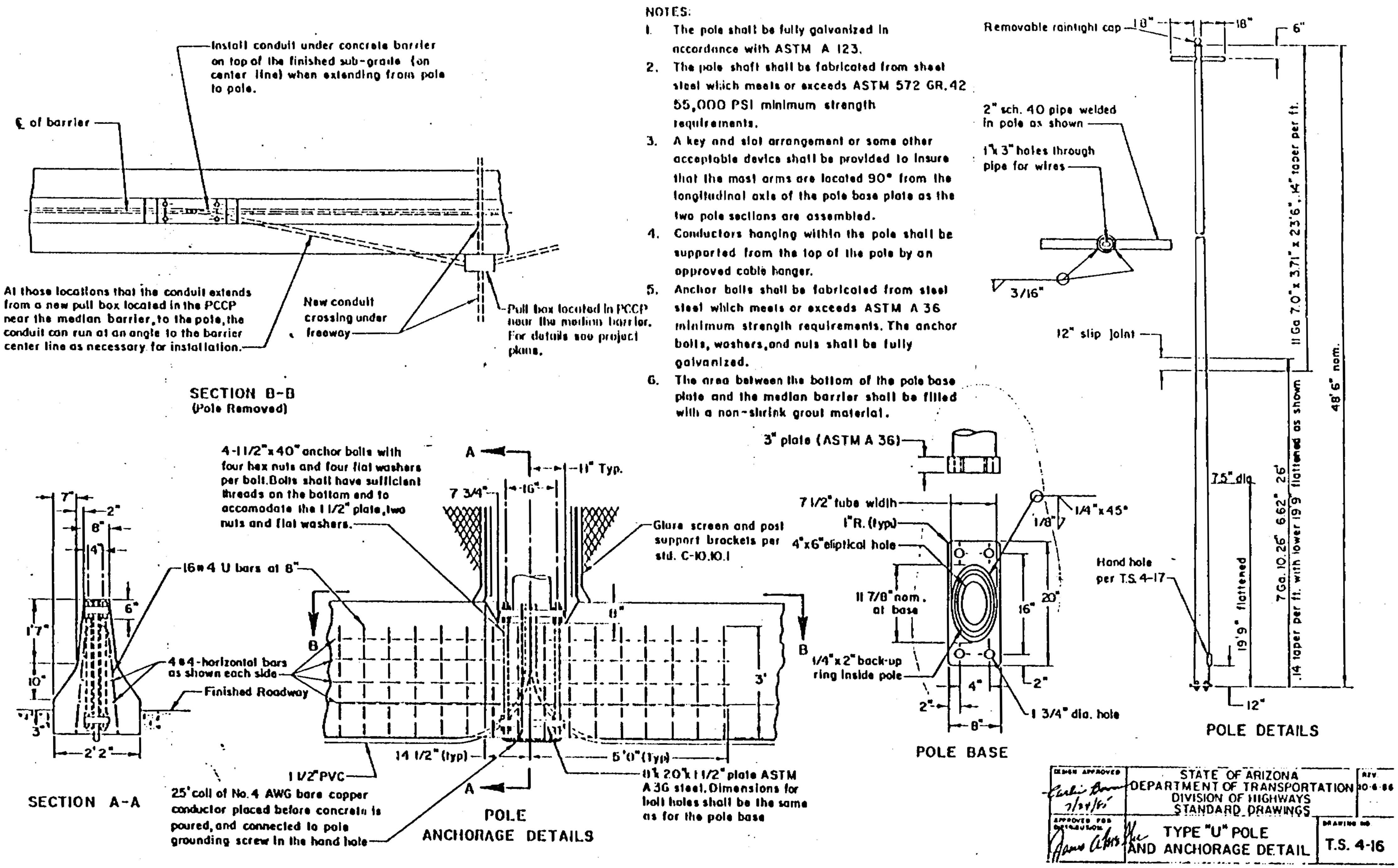


Figure 4

Source : Arizona Department of Transportation

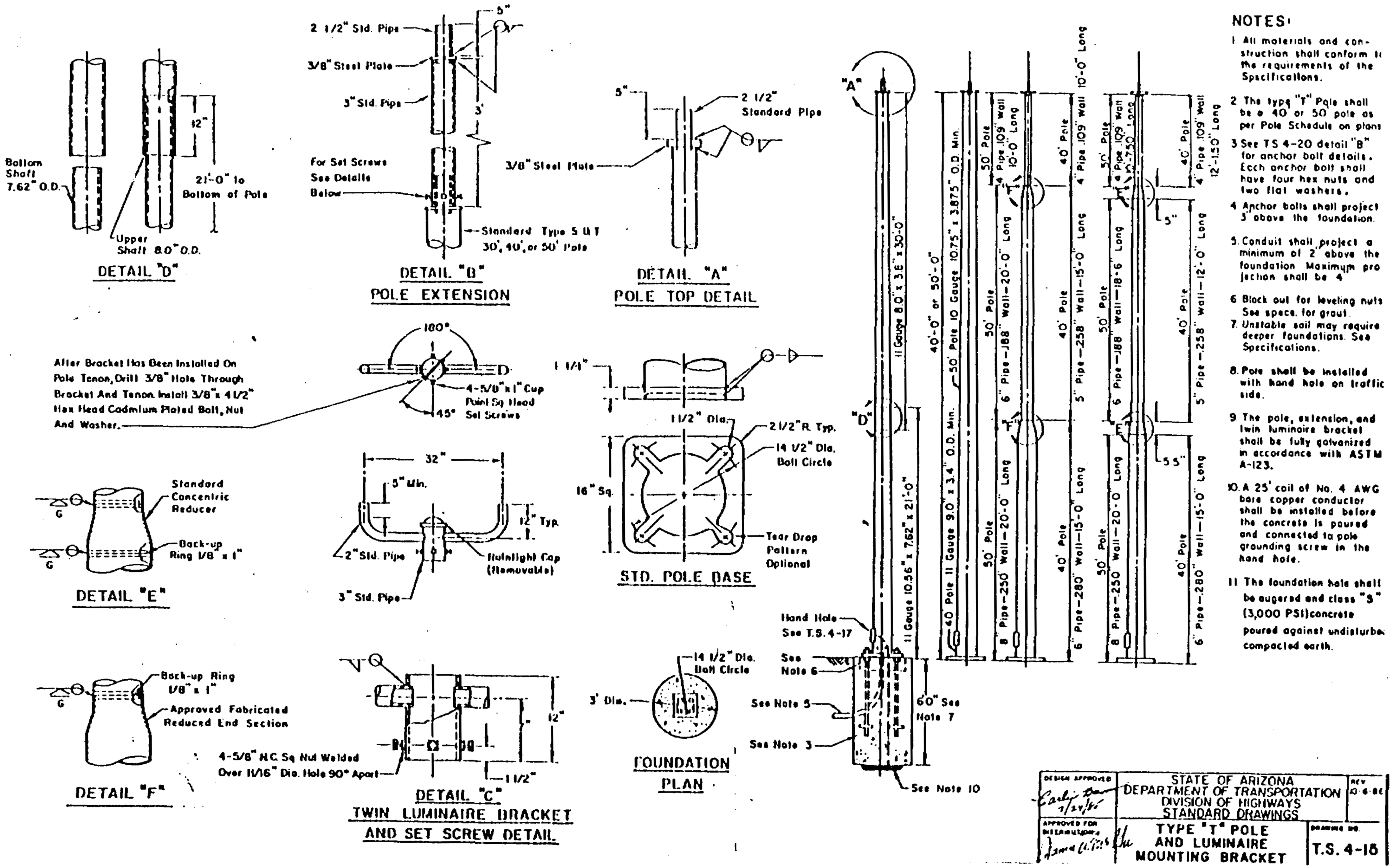
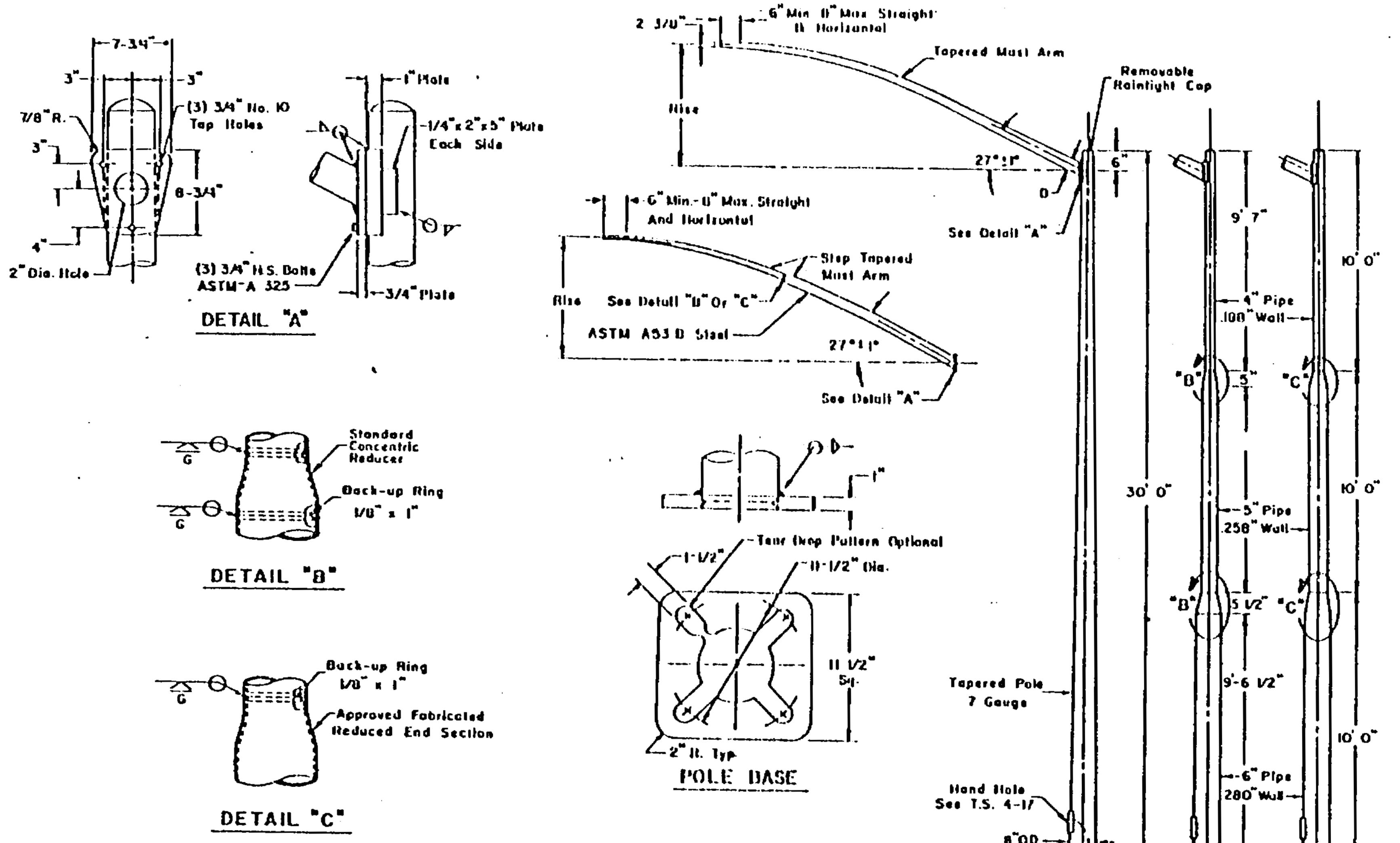
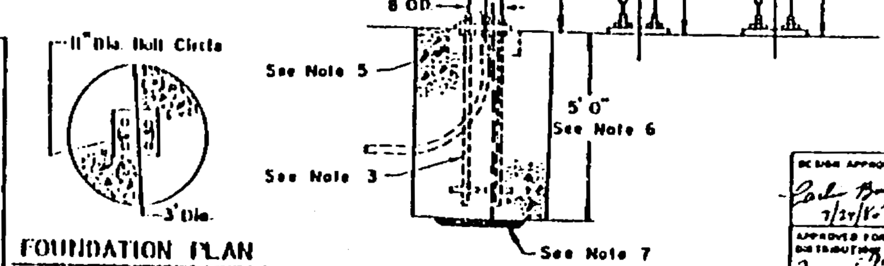


Figure 5

Source : Arizona Department of Transportation





NOTES:

1. All materials and construction shall conform to the requirements of the Specifications.
2. Pole, mast arm, and other parts shall have a protective finish as given in the Specifications.
3. See T.S. 4-20 detail "B" for anchor bolt details. Each anchor bolt shall have four hex nuts and two flat washers.
4. Anchor bolts shall project 3" above the foundation.
5. Block out for leveling nuts. See specs for grout
6. Unstable soil may require deeper foundation See Specification.
7. A 25' coil of No. 4 AWG bare copper conductor shall be installed before the concrete is poured and connected to pole grounding screw in the hand hole.
8. Conduit shall project a minimum of 2" above the foundation. Maximum projection shall be 4".
9. The foundation hole shall be augered and class "S" (3,000 PSI) concrete poured against undisturbed compacted earth.

POLE	TYPE of BASE
T.S. 4-7-1	STANDARD
T.S. 4-7-R	SLIP-AWAY
T.S. 4-7-L	See T.S 5-2

TAPERED MAST ARM						STEP TAPERED MAST ARM	
Length	Rise	Gauge	"D" Min.	Gauge	"D" Min.	Rise	Pipe Dia. Thickness And Length
6'	2' 0"	11	3 1/4"	10	3 3/8"	2' 0"	2.0 x .154 x 6'-0"
8'	2' 6"	11	3 1/2"	10	3 5/8"	2' 6"	2.0 x .154 x 8'-0"
10'	3' 8"	11	3 13/16"	10	3 7/8"	3' 0"	2.5 x .120 x 10'-0"
12'	4' 3"	11	4 1/16"	10	4 5/16"	4' 3"	2.5 x .120 x 12'-0"
15'	4' 9"	11	4 1/4"	10	4 3/4"	4' 9"	2.5 x .120 x 7'-0" & 3.0 x .156 x 8'-0"
18'	5' 9"	11	5 3/4"	10	5 3/16"	5' 9"	2.5 x .120 x 9'-0" & 3.0 x .156 x 9'-0"
20'	5' 9"	7	5 1/4"	7	5 1/4"	5' 9"	2.5 x .120 x 10'-0" & 3.0 x .156 x 11'-0"

STATE OF ARIZONA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
STANDARD DRAWINGS

TYPE "G" POLE AND MAST ARM

T.S. 4-7

REV 10-6-86

Figure 6

Source : Arizona Department of Transportation

easier. Besides this, the Arizona Department of Transportation utilizes a computer software called MICRO-SITE-LITE for estimating the lateral location and spacing of the luminaires.

POLICIES AND PROCEDURES USED BY OTHER STATES

The third task of this study was to review different procedures pertaining to median lighting and adopted by traffic agencies in states other than the state of Arizona. A short survey was designed for this purpose. The main objectives of this survey were to : survey different designs and procedures implemented around the country, survey studies related to the economics and safety cf median lighting, and determine the attitude of these traffic agencies with respect to further research effort on the topic of median lighting effectiveness and safety.

The survey questionnaire format was limited to two pages in length. A half page was used to define background information about median lighting and the purpose of this study. Seven questions followed the background section to address the three objectives outlined earlier. The survey was mailed to eighty-six members of the AASHTO traffic committee. These members represent the fifty departments of transportation in the U.S. A copy of the survey is shown in Appendix A.

Forty-three returns were received and the statistics of these responses are depicted in Table 4. The following conclusions were drawn from the survey statistics :

TABLE4 (SURVEY STATISTICS)

Number Of Questionnaires Sent Out = 86
Number Of Replies = 43

No.	Place	Policies & Procedures	Median Lighting Design/ Installation	Studies/ Research Conducted	Studies Confirm Economic Benefits	Accident Statistics	Future Research Recommended	Comments
		1	2	3	4	5	6	
1	Salt Lake City, UT	N	N	N	N	N	N	Y
2	St. Paul, MN	Y	Y	N	N	N	Y	Y
3	Springfield, IL	Y	Y	N	N	N	N	Y
4	Harrisburg, PA	N	Y	N	N	U	N	Y
5	Dover, DE	N	Y	N	N	N	Y	Y
6	South Holland, IL	N	Y	Y	Y	Y	N	Y
7	Sacramento, CA	N	N	N	N	N	N	Y
8	Ames, IA	N	Y	N	N	N	Y	Y
9	Atlanta, GA	N	Y	N	N	N	N	N
10	Columbus, OH	N	Y	N	N	N	Y	Y
11	Boise, ID	N	Y	N	N	N	Y	Y
12	Montgomery, AL	Y	Y	N	N	N	Y	N
13	Anne Arundel, MD	N	Y	Y	Y	N	Y	Y
14	Columbia, SC	N	Y	N	N	N	Y	N
15	Frankfort, KY	N	Y	N	N	N	Y	N
16	Olympia, WA	N	Y	N	N	N	N	Y
17	Huntsville, AL	U	N	N	N	N	N	N
18	Santa Fe, NM	N	Y	N	N	N	Y	Y
19	Lansing, MI	N	Y	N	N	N	N	Y
20	Raleigh, NC	N	Y	N	N	N	N	N
21	Helena, MT	N	N	N	N	N	N	Y
22	Rockville, MD	N	Y	N	N	N	Y	N
23	Montpelier, VT	N	N	N	N	N	N	N
24	Jefferson City, MO	Y	Y	Y	Y	N	Y	Y
25	Garland, TX	Y	Y	N	N	N	N	Y
26	MAINE	N	Y	N	N	N	N	Y
27	Pierre, SD	N	N	N	N	N	Y	Y
28	Tucson, AZ	Y	Y	Y	Y	Y	Y	N
29	Oklahoma City, OK	Y	Y	Y	Y	N	N	Y
30	Austin, TX	Y	Y	Y	Y	Y	Y	Y
31	Arlington, TX	Y	Y	N	N	Y	Y	Y
32	Charleston, WV	N	Y	N	N	N	N	Y
33	Concord, NH	N	Y	N	N	N	N	Y
34	Indianapolis, IN	N	N	N	N	N	Y	Y
35	Honolulu, HI	N	Y	N	N	N	Y	Y
36	Little Rock, AR	N	Y	N	N	N	N	Y
37	Pleasanton, CA	U	Y	N	N	Y	Y	Y
38	Boston, MA	Y	Y	Y	Y	N	Y	Y
39	Tallahassee, FL	N	Y	N	N	N	Y	Y
40	Trenton, NJ	Y	Y	N	N	N	Y	Y

41 Salem, OR	Y	N	N	N	N	Y	Y
42 Baltimore, MD	N	Y	N	N	N	Y	N
43 Phoenix, AZ	N	Y	N	N	N	Y	Y
Totals :-							
	#1	#2	#3	#4	#5	#6	Comments
Yes (Y)	12	35	7	7	5	25	33
No (N)	29	8	36	36	37	18	10
Not Known (U)	2	0	0	0	1	0	-
	43	43	43	43	43	43	43

1) Twelve agencies reported that they have policies and procedures regarding highway median lighting (35 percent of total response).
2) The majority of the agencies (35 responses) indicated that they have been involved in median lighting design and/or median lighting installations (81 percent of total response).
3) Only seven agencies reported that they have conducted studies on the subject of median lighting effectiveness and safety (16 percent of total response).
4) All seven agencies that reported studies confirmed the economic advantages of such strategy.
5) Only five agencies indicated that they have statistics on accidents resulting from motorists running into median lighting poles (around 12 percent of total response).
6) Thirty-three responders provided written comments. Selected statements provided by the responders are listed in Appendix B.

Although only twelve agencies (representing 11 states) reported policies and or procedures, it is the researcher's opinion that no further research is needed in the area of uniform policies. Guidelines provided in the AASHTO manual, and other standards published by cities should suffice at this time. The reader is referred to the guidelines provided by the City of Arlington, Texas and attached to this document as Appendix C.

It is the consensus of the responders that median lighting is a cost-effective strategy for highway lighting. Furthermore, it was concluded that when median lighting is used, little hazard is imposed on highway traffic. Only twelve percent reported accidents resulting from median lighting.

The main concern raised by several agencies was the safety of the maintenance crew working in the vicinity of the median. For narrow medians, utility trucks conduct their maintenance activity from the median lane (the high speed lane of the facility) resulting in temporary work zone signing and marking. Some agencies indicated that utility companies refused to serve the lighting fixtures used in medians on selected facilities in their state. Other state agencies recommended a minimum lateral clearance of 20 feet between the light pole and median lane pavement edge.

It is apparent that any future research should be directed towards developing techniques for maintaining median lighting hardware without jeopardizing the crew's safety. The next section describes a work plan for a recommended research project.

RECOMMENDATIONS FOR FUTURE RESEARCH

The assessment of the literature and current practice reveals that the use of median lighting systems are economical and effective. The area that needs more research effort is public safety associated with lighting routine maintenance. A study should be conducted to assess the economic costs of closing the median lane of a facility for a short period while performing a maintenance activity. This study should investigate operational strategies for median lighting maintenance and their feasibility.

WORK PLAN

PROBLEM STATEMENT

The use of median lighting at narrow highway medians may cause hazard for lighting maintenance crew. The median lane is blocked for a period long enough to conduct the maintenance activity. For heavily traveled facilities, traffic delay increases and long queues may develop. Traffic accidents could result, and the road user cost would therefore increase. The question that needs to be addressed at this point is at what levels of traffic demand and median width is median lighting economically justifiable?

STUDY OBJECTIVES

The proposed study has the following objectives :

1. Determine the road user costs associated with median lighting for different traffic demand and median widths.
2. Determine the savings in capital, maintenance and operation costs of median lighting for the same levels of traffic demand and median widths.
3. Determine the net road user costs and generate median lighting warrants.
4. Develop and evaluate several strategies to maintain median lighting hardware with minimum disruption to traffic operation and safety.

TASK 1 - MEDIAN LIGHTING COSTS

The costs of median lighting are measured in terms of increase in road user costs. Traffic accidents, travel delay, and fuel consumption are the three measures of effectiveness proposed for this task. Several hypothetical settings have to be selected to represent different traffic demand and median width. Accident rates developed in previous studies are utilized to estimate the number of accidents resulting from lane closures. Travel delay and excess fuel consumption may be determined using appropriate road user cost formulae.

TASK 2 - MEDIAN LIGHTING BENEFITS

Benefits accrued from median lighting are measured in reductions in road user costs. Light spacings, median widths and lane closure durations are varied and the reduction in road user cost figures are calculated.

TASK 3 - WARRANTS FOR ECONOMICAL MEDIAN LIGHTING

Net road user cost is then calculated for all hypothetical settings and warrants for median lighting installations are developed.

TASK 4 - MAINTENANCE STRATEGIES

Strategies to maintain median lighting hardware need to be developed and economically evaluated. The main goal of these strategies is to minimize disruption to traffic operation during maintenance activities.

TASK 5 - PREPARE FINAL REPORT

Prepare a final report which documents all assumptions, economic analyses, and findings of the research project.

Anticipated Project Duration : 12 months.

Estimated Budget : $ 70,000.00

REFERENCES

1. I.E.S. Lighting Handbook, Fifth Edition, Illuminating Engineering Society, N.Y., 1972.

2. Roadway Lighting Handbook, U.S. Department of Transportation, Washington D.C., 1978.

3. "An Informational Guide for Roadway Lighting", American Association of State Highway and Transportation Officials, Washington D.C., 1976.

4. Walton Ned E. and Messer, C.J., "Warranting Fixed Roadway Lighting From a Consideration of Driver Work Load", Transportation Research Record No. 502, National Research Council, Washington D.C., 1974.

5. Walton Ned E. and Rowan, N.J., "Warrants for Highway Lighting", NCHRP Report 152, National Co-operative Highway Research Program, Washington D.C., 1974

6. Addendum to the Roadway Lighting Handbook, Designing the Lighting System - Using Pavement Luminance, U.S. Department of Transportation, Washington D.C., 1983.

7. Traffic Engineering - Policies, Guides and Procedures, Arizona Department of Transportation, Arizona, 1982.

8. "American National Standard Practice for Roadway Lighting", Illuminating Engineering Society - American National Standards Institute, New York, 1977.

APPENDIX A

ARIZONA DEPARTMENT OF TRANSPORTATION

206 South Seventeenth Avenue Phoenix, Arizona 85007

ROSE MOFFORD
Governor

CHARLES L. MILLER
Director

ARIZONA TRANSPORTATION RESEARCH CENTER

September 19, 1988

Subject: Research Study HPR-PL-1(24) Item 835
"Analysis of Median Lighting"

Gentlemen:

The Center for Advanced Research in Transportation at Arizona State University under a contract with the Arizona Transportation Research center is currently developing a state-of-the-art report on median lighting. The report is aimed at reviewing current plans and practices adopted by public agencies to deal with the problem of economics and safety of highway median lighting.

I would appreciate it if you would take a few minutes to respond to the short questionnaire which is enclosed. The questionnaire is self explanatory. However, if you have any questions, please do not hesitate to contact Dr. Essam Radwan, the Principal Investigator of this study, at (602) 965-2885.

Please respond by October 10, 1988. Thank you for your cooperation.

Sincerely,

F. R. McCullagh

Frank R. McCullagh, P.E.
Assistant State Engineer
Arizona Transportation Research
Center

Arizona State University

College of Engineering and Applied Sciences
Center for Advanced Research in Transportation
Tempe, Arizona 85287-6306
602/965-2001
TLX 165878 COLL ENG TMPE

Highway Lighting is intended to facilitate a safe movement of vehicular traffic during the nighttime. The placement of light poles and luminaires is an integral part of an effective lighting system. Median lighting is popular due to its economic advantage. Placing the luminaire supports in the median reduces the number of supports required by one-half over that required for side-mounted configurations. In addition to the economic advantage of median lighting, there is a service advantage; median lighting simply provides better visibility. The highest level of illumination is along the median and inside higher speed lanes.

When median lighting is used, the lateral clearance from the traveled way is usually less than when placed on the side of the roadway. This placement may or may not adversely affect roadway safety since in urban areas, the luminaire pole is usually mounted on top of the median barrier.

The purpose of this survey is to review current policies and procedures used by various traffic engineering agencies, and investigate their experience with using median lighting. Your response to this survey will be greatly appreciated.

1. Does your state have policies or procedures regarding highway median lighting?

    _____ Yes (Please provide a copy)
    _____ No

2. Has your agency been involved in median lighting design and/or median lighting installations?

    _____ Yes
    _____ No (Proceed to question 5)

3. Did your agency conduct studies to assess median lighting effectiveness and safety?

    _____ Yes
    _____ No (Proceed to question 5)

4. Did these studies confirm the economic advantages of such strategy?

   ______ Yes (Please provide a copy)
   ______ No (Please provide a copy)

5. Does your agency have statistics on accidents resulting from motorists running into median lighting poles?

   ______ Yes (Please provide)
   ______ No

6. Do you recommend further research on the topic of median lighting effectiveness and safety?

   ______ Yes (Use the space below to elaborate)
   ______ No

7. Do you have anything to add?

Please respond by October 7 to:

Dr. Essam Radwan
Center for Advanced Research in Transportation
Arizona State University
Tempe, Arizona 85287-6306

Thank you for your help.

APPENDIX B

Selected Comments of the Responders of the Survey

What follows in this section are comments of the State Agency officials regarding the usage of median lighting in response to the questionnaires sent out to them. The names and addresses of the responders are not included in the list.

o "Economic advantages must be weighted against safety, and of course the lighting objectives sought in the design. The decision to use or not to use the median areas for pole locations becomes a judgement factor on each project."

The following points were highlighted regarding median lighting :-

"a. Agree with economic advantages.

b. Median locations present greater hazard for maintenance people.

c. Poles in narrow medians have a higher probability of falling on roadways than the poles on the right hand side of the vehicle travel.

d. Common circuit for median poles with twin arms reduces system reliability."

o "Poles atop a concrete barrier are rarely hit because the barrier is designed to deflect the vehicle. Repair or relamping of median mounted units either requires a lane to be blocked or work immediately adjacent to a travel lane." This exposes the maintenance crew and personnel to high speed traffic.

o "The economic approach is simple: half the poles; half the cables and conduit (if required) and with proper design, half the luminaires and no mast arms. Life cycle costs are less since pole knockdowns are drastically cut due to the inherent protective features of the roadway median."

o "Need research in the area of cost-effectiveness of median lighting as compared to side lighting. Also, review of maintenance activities associated with each location."

o "We install median lighting due to cost savings. We have not compared median lighted sections with shoulder or high level lighted sections. We have compared illuminated sections to non-illuminated sections and have been unable to find a relationship between accidents and illumination."

o "We also prefer staggered lighting if the double arm in the median is too spotty. We also found that one side lighting on a 70 feet or less roadway width to be quite acceptable. We don't usually put lighting standards in the median as the Utility Company feels it is safer working with slower right lane traffic and possibly having the maintenance equipment out of the Driving (high speed) lanes. Also, we like to design for a 6 feet minimum setback from the face of the curb and most medians are less than 12 feet."

o "I understand that for our state projects FHWA has advised they (that) will not approve any median street lighting installation where median widths are 40 feet or less. Therefore, any further study seems questionable."

o "There have already been enough studies that indicate the effectiveness of median lighting. Safety of median lighting depends on the same factors that affect one side/ outside lighting, (lateral distance), pole density/spacing, traffic volumes, speed, breakaway or not, pole location in or on median barrier, etc.)

Also provided with the reply were the highway lighting safety guidelines and reports on comparative analysis of project alternatives and breakaway pole dynamics. The results indicated that low-velocity collisions (20 mph or less) are most hazardous. There is danger from vehicle deceleration and from the falling shaft. Where low velocity collisions are most probable, lightweight supports and bases possessing the lowest base resistance should be used. For normal Aluminum or Steel supports (30 and 40 feet mounting heights) the danger of a hazardous collision decreases with an increase in vehicle collision velocity. The lower limit for a low-hazard collision (from the standpoint of the support falling on the vehicle) is approximately 35 mph. For larger supports (50 feet mounting height and higher) it appears that more hazardous collisions (from the same standpoint) can occur with collision velocities as high as 45 mph. This limit could be reduced somewhat by using bases with low base fracture energies.

o "In the early 70's, we researched the use of median lighting. The research included full-scale crash tests of 50 feet twin-arm steel lighting poles." The research report was attached to the response. "For median widths less than 40 feet we placed non-breakaway poles between the flex beam barrier. With the advent of the concrete median barrier, we developed a specially-shaped pole that would fit the top of the barrier and placed these non-breakaway poles on top of the barrier. We have had a few of these knocked down when the upper structure of the truck impacts the pole. We have found that, for high-volume urban freeways (ADT > 100,000), maintenance of median lighting is hazardous for the maintenance personnel, and traffic handling during maintenance is expensive. For these freeways, we are now using high-mast lighting, placing the poles in the side separation away from the traffic. A recommended area of future research is the comparison of the use of median lighting versus high-mast lighting for high volume freeways.

o "It is the unwritten policy of the state to use median lighting for temporary illumination during construction or else if absolutely necessary."

o "Following areas of research are recommended :-
1. Minimum illumination/luminance for suburban arterial not pedestrian related.
2. Cost-effectiveness and desirability of breakaway luminaire structures in suburban environment include factors such as median width/parkway width, speed, driveways and intersections.
3. How to achieve good lighting distribution when lighting height restricted due to overhead electrical distribution."

Also provided is a record of fatal accidents involving light poles and vehicles in the last five years. Out of the 10 accidents only one involved a median lighting pole. Among them, 7 were due to alcohol and drugs, 2 due to speeding and 1 due to inattention.

APPENDIX C

STANDARDS FOR ARTERIAL AND MAJOR COLLECTOR STREET LIGHTING IN THE CITY OF ARLINGTON, TEXAS

I. PURPOSE

The following standards shall govern the design and installation of street lighting for arterial and major collector streets in the City of Arlington. For street light design and specifications on roadways greater than 38 ft. in width, these standards supersede the City of Arlington, Traffic and Transportation Division, Street Light Department's Street Light Installation "Standard Specifications and Design Criteria," dated April 10, 1984. However, applicable portions of Item 4.0, Street Light Plans, of the 1984 standard shall guide in the preparation of the street light plans for arterial and major collector streets. For the purposes of these standards, the following are classified as arterial and major collector streets:

A. A major collector as classified in the City's Thoroughfare Plan, typically being a 4-lane undivided roadway typically within a 65 ft. or 70 ft. right-of-way (r.o.w.).

B. A minor arterial in the City's Thoroughfare Plan typically being a four-lane boulevard typically within a 90 ft. r.o.w.

C. A major arterial as classified in the City's Thoroughfare Plan typically being a six-lane boulevard typically within a 120 ft. r.o.w. Included in the classification of a major arterial are roadways which are to be constructed as four-lane boulevards within 120 ft. of r.o.w. but are to be ultimately expanded to six-lane boulevards. The two outside lanes are normally constructed as Phase I on such roadways. The inside lanes on each side are constructed as Phase II in the future.

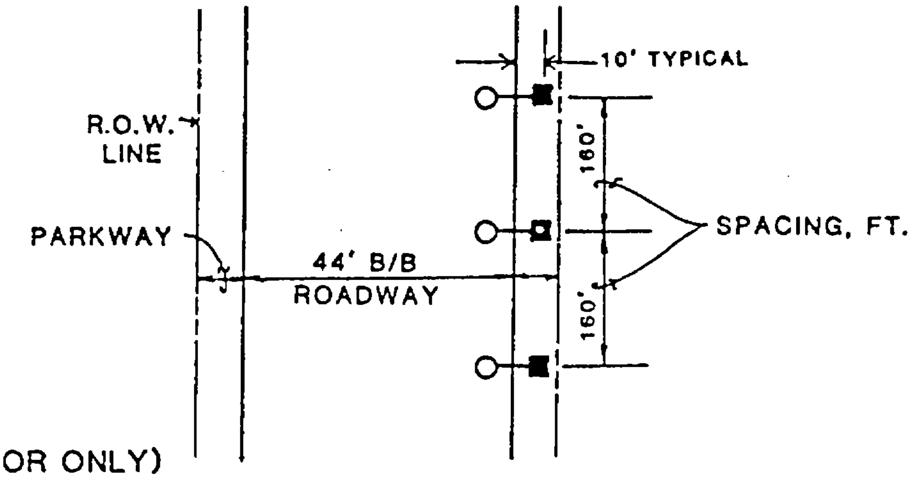
II. DESIGN CRITERIA

A. LIGHTING CONFIGURATIONS

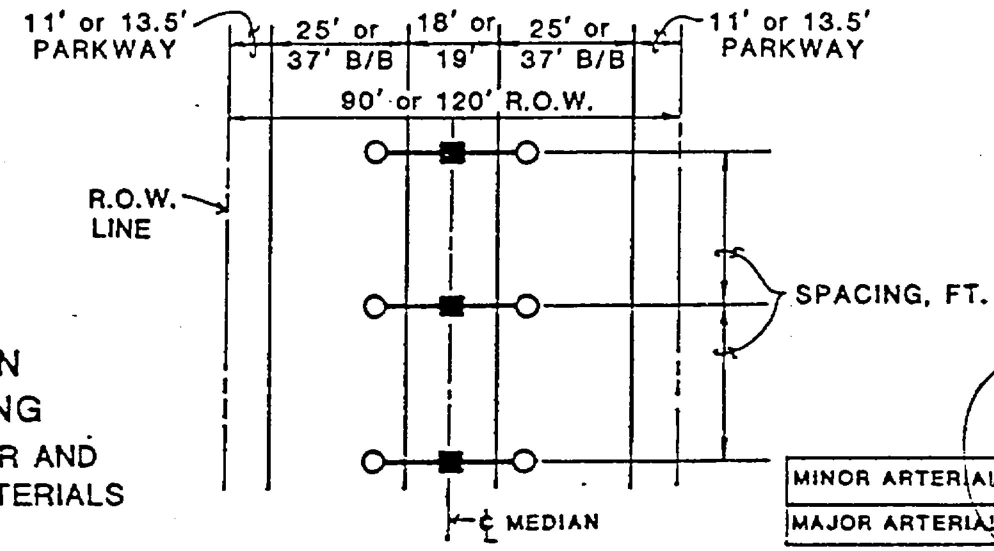
The following lighting configurations are to be used in street lighting. These configurations are illustrated in Figure II.1.

1. One-side lighting - light poles installed within the parkway on one side of the roadway. To be used along 4-lane undivided roadways only.

ONE-SIDE LIGHTING
(MAJOR COLLECTOR ONLY)

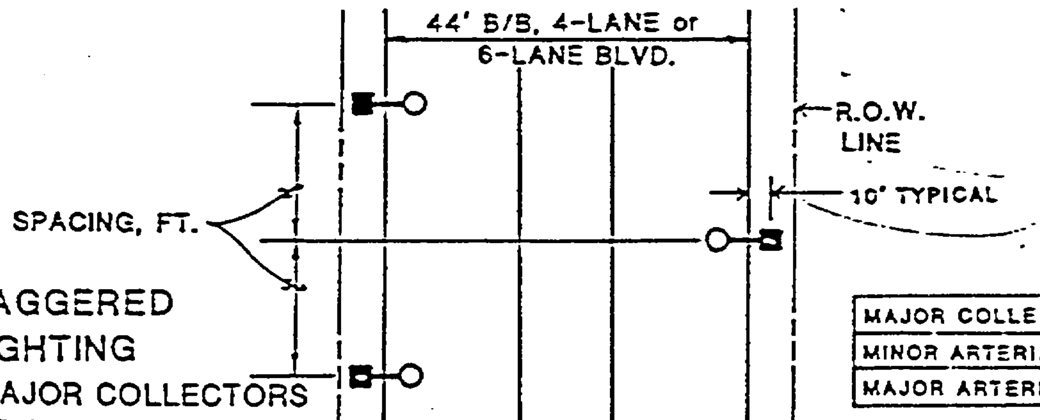


MEDIAN LIGHTING
FOR MINOR AND MAJOR ARTERIALS



	SPACING, FT.
MINOR ARTERIAL	210'
MAJOR ARTERIAL	190'

STAGGERED LIGHTING
FOR MAJOR COLLECTORS AND MINOR AND MAJOR ARTERIALS



	SPACING, FT.
MAJOR COLLECTOR	160'
MINOR ARTERIAL	130'
MAJOR ARTERIAL	100'

FIGURE II.1 - LIGHTING CONFIGURATIONS

NOT TO SCALE

JUNE 9, 1987

II. DESIGN CRITERIA (Continued)

A. LIGHTING CONFIGURATIONS (Continued)

2. Median lighting - light poles with twin arms and luminares installed at the center of the median of four- and six-lane boulevards. Lighting poles within the median of an initial four-lane boulevard which is to be expanded to a six-lane boulevard shall be designed such that the poles need not be relocated when the roadway is expanded (i.e. at left turn lanes, and transitions for left turn lanes).

3. Staggered lighting - light poles installed in an alternating fashion within parkways along both sides of the roadway. This configuration is the preferred design in non-divided roadways and can be used in four- and six-lane boulevards when median lighting in boulevards is not feasible.

B. SPACING BETWEEN LIGHT POLES ALONG ROADWAY

1. Intent of Standard Spacing

   The spacings for specific types of configurations were derived to meet the following illumination design criteria for arterial and major collector street lighting:

   a) $E_{h(ave)}$ - (the Average Maintained Horizontal Illumination in ft.candles) shall be $\geq$ 0.90 fc.

   b) $E_{h(ave)}$/Min. - (the average maintained horizontal illumination value divided by the lowest illumination point encountered within the area of roadway being lighted) shall be $\leq$ 3.0.

   c) Max./Min. - (the highest illumination point divided by the lowest illumination point encountered within the area of roadway being lighted) shall be $\leq$ 9.0.

2. Standard Spacing Along Roadway

   The standard spacing distance between all poles in non-intersection areas shall be as shown in Figure II.2. (See Section III for spacings in and near

II. DESIGN CRITERIA (Continued)

B. SPACING BETWEEN LIGHT POLES ALONG ROADWAY (Continued)

2. Standard Spacing (Continued)

intersections.) In order to meet actual field conditions and avoid obstructions, a spacing less than standard can be used to clear obstructions, or the spacing may be increased no more than 15 ft. between specific poles where necessary in order to resolve conflict with specific obstructions.

Any deviation requiring a tolerance of more than 15 ft. shall require submittal of calculated E_h (ave), E_h(ave)/Min. and Max./Min. values indicating compliance with the design criteria in II.B.1. above.

FIGURE II.2 - SPACING

	STANDARD SPACING (FT.)		
	ONE-SIDE LIGHTING	MEDIAN LIGHTING	STAGGERED LIGHTING
MAJOR COLLECTOR	160	N.A.	160
MINOR ARTERIAL	N.A.	210	130
MAJOR ARTERIAL	N.A.	190	100

NOTE: THE VALUES ABOVE MAY BE INCREASED BY A 15-FT. TOLERANCE ONLY WHEN STANDARD SPACING CANNOT BE OBTAINED DUE TO AN OBSTRUCTION WHERE POLE IS AT STANDARD SPACING (i.e. DRIVEWAYS, INTERSECTING ROADWAY, ETC.) SPACING MAY BE LESS THAN STANDARD AS PRACTICAL TO CLEAR OBSTRUCTIONS.

The standard spacings above conform to the illumination design criteria discussed in Section II.B.1. The E_h(ave), E_h(ave)min., and max./min. illumination values were computed in conformance to the Illumination Design Procedure as discussed in Chapter 6, "Designing the Lighting System", Roadway Lighting Handbook, U.S. Department of Transportation, Federal

II. DESIGN CRITERIA (Continued)

B. SPACING BETWEEN LIGHT POLES ALONG ROADWAY (Continued)

Highway Administration, December 1978. A roadway lighting program, LUX, in conjunction with the photometric data for the flat lens luminaire as specified in Section IV, was utilized in computing the illumination values. LUX is available from JOLINKO Enterprises, Inc., #8 Lake Boulevard, Vicksburg, Mississippi 39180 (phone number 601/638-0484).

3. Adjustment for Topographic Height Variations

Where the base of the lighting standard is higher or lower by 5 ft. than the adjacent top of curb, a non-standard spacing between such adjacent poles shall be specifically calculated to meet the required E_h(ave), E_h(ave)/min., and max./min. illumination values as specified in Section II.B. The illumination value computations shall be submitted to the City's Traffic Department.

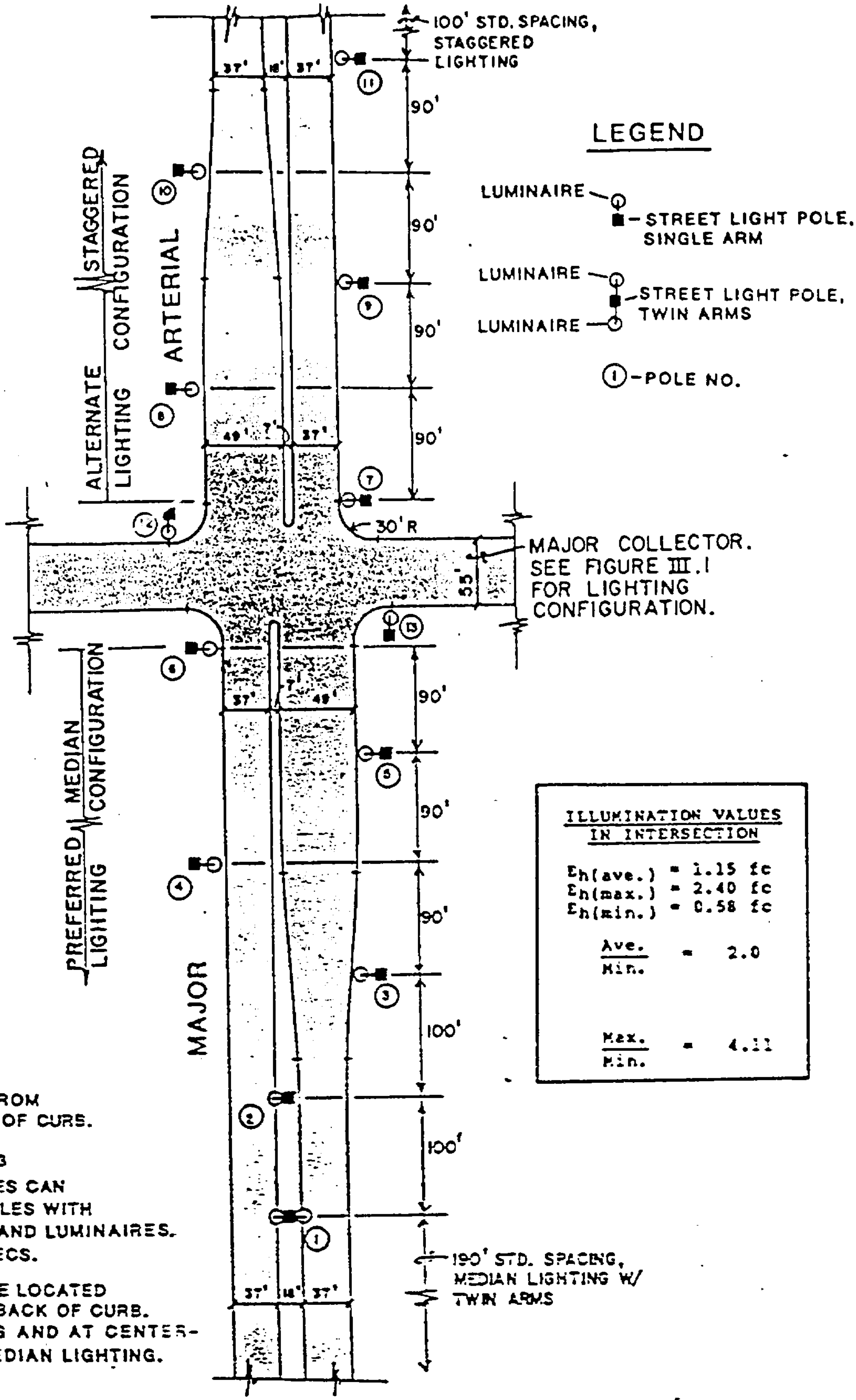
4. Lateral Clearances

Where sidewalks have not been constructed along parkways or where existing sidewalks do not conflict with proposed pole locations, poles shall be installed 10 ft. from the back of curb for one-side or staggered lighting. Where existing sidewalks conflict with the preferable 10-ft. offset from the back of curb, the City of Arlington Transportation Department shall be consulted to confirm if other offsets would be preferred to avoid conflict with and intrusion into existing sidewalks.

Poles shall be constructed at the center of the median for median lighting.

III. INTERSECTION LIGHTING

Refer to Figure III.1 through III.5 for lighting configurations and spacings required at typical intersection. At and near intersections these spacings and configurations shall govern instead of the standard non-intersection spacings discussed in Section II. Intersection lighting configurations, as shown in Figure III.1 through III.5, were designed as a matter of practicality (jointly utilizing proposed



ILLUMINATION VALUES IN INTERSECTION

$E_{h(ave.)}$	=	1.15 fc
$E_{h(max.)}$	=	2.40 fc
$E_{h(min.)}$	=	0.58 fc
$\frac{Ave.}{Min.}$	=	2.0
$\frac{Max.}{Min.}$	=	4.11

NOTES:

1.) ROADWAY DIMENSIONS FROM BACK OF CURBS TO BACK OF CURBS.

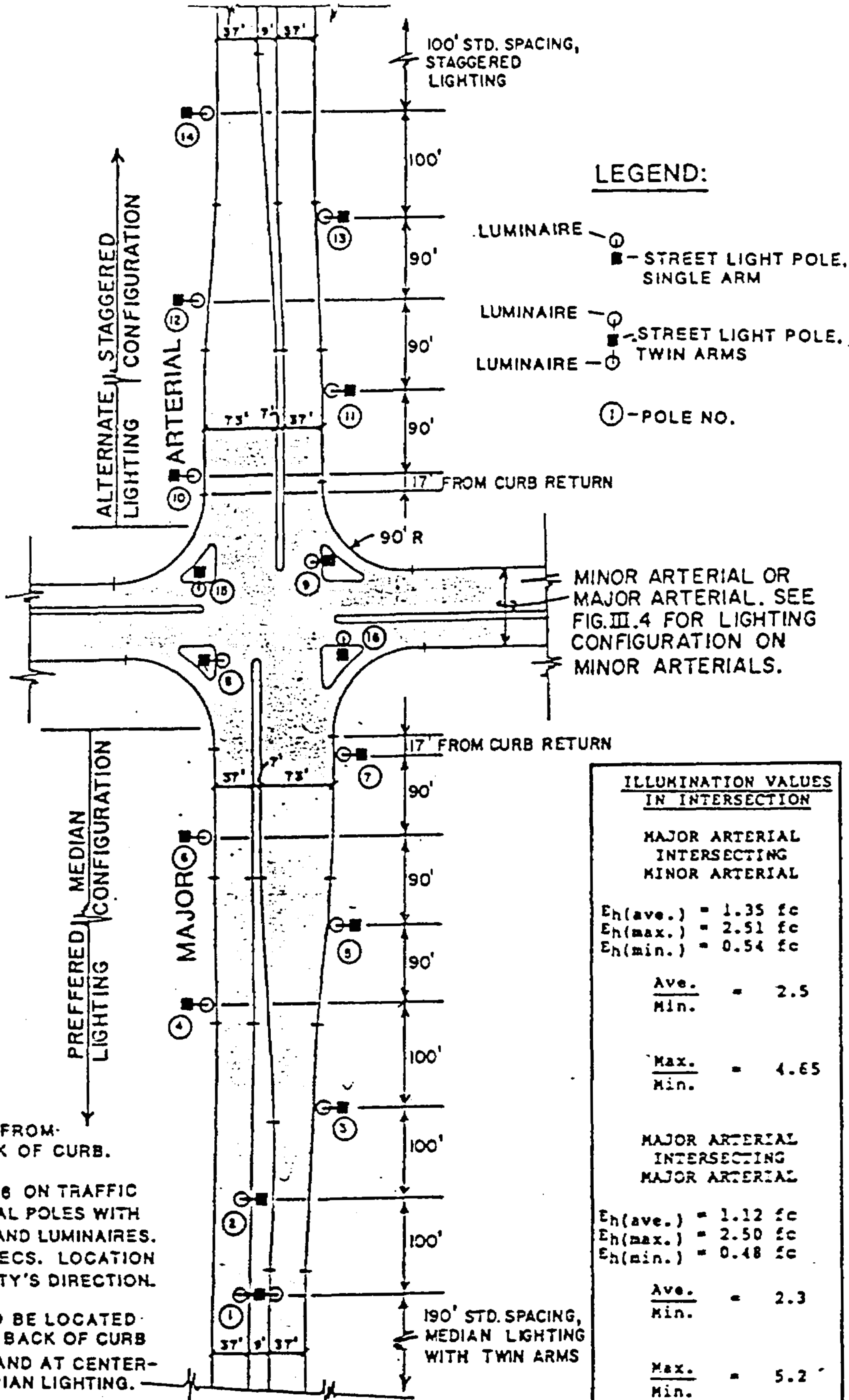
2.) POLE NOS. 6, 7, 12, & 13 AT CURB RETURNS. POLES CAN POSSIBLY BE SIGNAL POLES WITH DAVIT ARM EXTENSIONS AND LUMINAIRES. SEE SECTION III THIS SPECS.

3.) STEET LIGHT POLES TO BE LOCATED TYPICALLY 10 FT. FROM BACK OF CURB. FOR PARKWAY LIGHTING AND AT CENTER-LINE OF MEDIAN FOR MEDIAN LIGHTING.

FIGURE III.3 - INTERSECTING LIGHTING FOR : MAJOR ARTERIAL INTERSECTING A MAJOR COLLECTOR

NOT TO SCALE

JUNE 9, 1987



ILLUMINATION VALUES IN INTERSECTION

MAJOR ARTERIAL INTERSECTING MINOR ARTERIAL

$E_{h(ave.)}$ = 1.35 fc
$E_{h(max.)}$ = 2.51 fc
$E_{h(min.)}$ = 0.54 fc

Ave./Min. = 2.5

Max./Min. = 4.65

MAJOR ARTERIAL INTERSECTING MAJOR ARTERIAL

$E_{h(ave.)}$ = 1.12 fc
$E_{h(max.)}$ = 2.50 fc
$E_{h(min.)}$ = 0.48 fc

Ave./Min. = 2.3

Max./Min. = 5.2

ɔWAY DIMENSIONS FROM K OF CURB TO BACK OF CURB.

E NOS. 8, 9, 15, & 16 ON TRAFFIC NDS SHALL BE SIGNAL POLES WITH T ARM EXTENSIONS AND LUMINAIRES. SECTION III THIS SPECS. LOCATION GNAL POLES PER CITY'S DIRECTION.

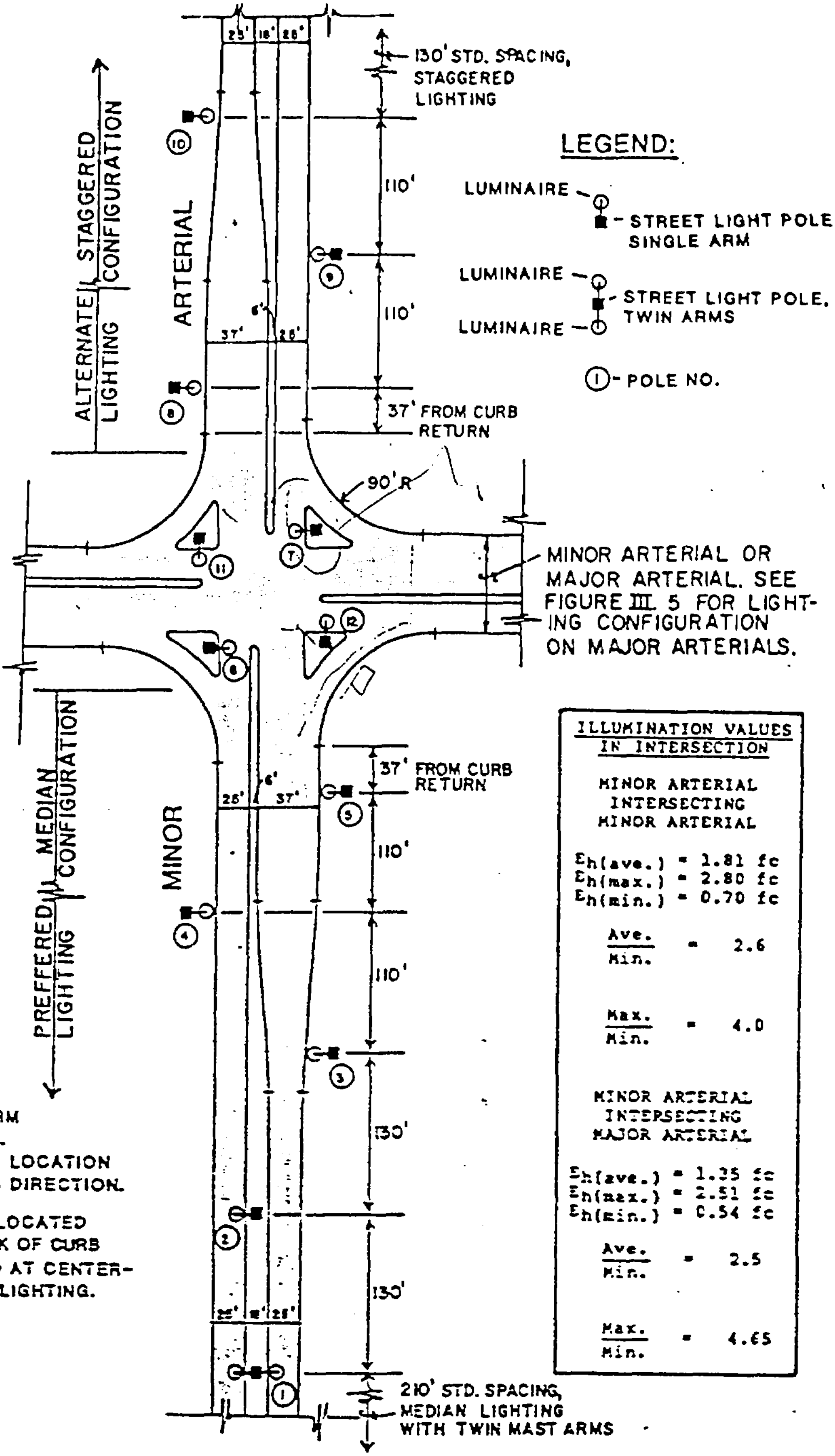
ET LIGHT POLES TO BE LOCATED ALLY 10 FT. FROM BACK OF CURB 'ARKWAY LIGHTING AND AT CENTER- OF MEDIAN FOR MEDIAN LIGHTING.

II.5 - INTERSECTION LIGHTING FOR:

MAJOR ARTERIAL INTERSECTING A MINOR ARTERIAL OR MAJOR ARTERIAL

NOT TO SCALE

JUNE 9, 1987



ILLUMINATION VALUES IN INTERSECTION

MINOR ARTERIAL INTERSECTING MINOR ARTERIAL

$E_{h(ave.)}$ = 1.81 fc
$E_{h(max.)}$ = 2.80 fc
$E_{h(min.)}$ = 0.70 fc

Ave./Min. = 2.6

Max./Min. = 4.0

MINOR ARTERIAL INTERSECTING MAJOR ARTERIAL

$E_{h(ave.)}$ = 1.35 fc
$E_{h(max.)}$ = 2.51 fc
$E_{h(min.)}$ = 0.54 fc

Ave./Min. = 2.5

Max./Min. = 4.65

NOTES:

1.) ROADWAY DIMENSIONS FROM BACK OF CURB TO BACK OF CURB.

2.) POLE NOS. 6, 7, 11, & 12 ON TRAFFIC ISLANDS SHALL BE SIGNAL POLES WITH DAVIT ARM EXTENSIONS AND LUMINAIRES. SEE SECTION III THIS SPECS. LOCATION OF SIGNAL POLES PER CITY'S DIRECTION.

3.) STREET LIGHT POLES TO BE LOCATED TYPICALLY 10 FT. FROM BACK OF CURB FOR PARKWAY LIGHTING AND AT CENTERLINE OF MEDIAN FOR MEDIAN LIGHTING.

FIGURE III.4 - INTERSECTING LIGHTING FOR:
MINOR ARTERIAL INTERSECTING A MINOR ARTERIAL OR MAJOR ARTERIAL

NOT TO SCALE

traffic signal poles at intersections for arm support) and uniformity. For major collector and arterial intersections having geometric layouts which vary from those shown in the above-referenced figures, street light poles shall be located to achieve the "illumination values" shown on the figure for the most comparable intersection layout. Alternate designs or intersection lighting locations which vary from those shown in the above-referenced figures shall be reviewed by City upon submittal of calculations indicating conformance to lighting design criteria.

For intersection lighting layouts, the City's Traffic Department shall be consulted to determine if traffic signal poles shall be required in the future at the intersection. Where required and if directed by the Department, the lighting standards shall be integrated with the traffic signal pole. Refer to Section 11, Steel Poles and Arms of "Traffic Signal Specifications", Department of Transportation, City of Arlington, Texas, with the latest revisions, for specifications. For details, refer to "Signal Poles, Mast Arms, and Davit Extensions" detail sheet and "Foundation Details" detail sheet, Department of Transportation, City of Arlington, with latest revisions. The City's Department of Transportation shall be consulted for which pole type number to use.